# NATURAL FLOWS
# FOR
# WILLOW CREEK BASIN

Prepared by : S. J. Figliuzzi, P. Eng.
Submitted by : A. M. Mustapha, P. Eng.
June, 1985

Alberta
ENVIRONMENT
Water Resources Management Services
Technical Services Division
Hydrology Branch

JUNE, 1985

## SYNOPSIS

As part of a water management planning program for the Willow Creek basin, natural flows are developed for seven hydrometric station locations and four project sites in the basin. The flows are monthly mean values for the period 1912 to 1983.

The natural flows at hydrometric station locations are derived by removing the influence of man-made projects from the recorded data. The influence of a man-made project is determined from water use return information in Water Rights files maintained by Alberta Environment. Since the period of record for the hydrometric station locations does not cover the entire 1912 to 1983 study period, naturalized streamflow are extended to the study period by means of regression equations developed in the study.

Natural flows at Project sites are developed using an area relation between the project site and nearby hydrometric sites for which extended natural flows were developed.

The monthly natural flows are reported in printed form within this report and are also contained, by Hydrology Branch, in a computer data base for future use.

## TABLE OF CONTENTS


| | Page Number |
|---|---|
| LIST OF TABLES ..... | iv |
| LIST OF FIGURES ..... | vii |
| 1. INTRODUCTION ..... | 1 |
| 2. BASIN GEOGRAPHY ..... | 3 |
| 3. STUDY APPROACH ..... | 5 |
| 4. BASIN WATER USE ..... | 7 |
| 5. NATURAL FLOWS AT HYDROMETRIC SITES ..... | 9 |
| 6. NATURAL FLOWS AT PROJECT SITES ..... | 11 |
| 7. DISCUSSION OF RESULTS ..... | 12 |

APPENDICES

Appendix A - Willow Creek Basin (J-Files)
Arrays of Historical Water Uses ..... 13

Appendix B - Willow Creek Basin (A-Files)
Arrays of Recorded Streamflow ..... 38

Appendix C - Willow Creek Basin (B-Files)
Arrays of Recorded Flows Adjusted to Natural .. 48

Appendix D - Willow Creek Basin (C-Files)
Arrays of Extended Natural Flows .....

Appendix E - Willow Creek Basin (G-Files)
Arrays of Natural Flows at Project Sites .....

## LIST OF TABLES


| Table Number | Item | Page Number |
|---|---|---|
| 3.1 | Locations of Historical Natural Flow Files .. | 5 |
| APPENDIX A | ..... | 13 |
| A-1 | Willow Creek Basin - Water Uses ..... | 14 |
| A-2 | Willow Creek above Chain Lakes Monthly Mean Flow Adjustments ..... | 28 |
| A-3 | Willow Creek below Lane Creek Monthly Mean Flow Adjustments ..... | 29 |
| A-4 | Willow Creek near Claresholm Monthly Mean Flow Adjustments ..... | 30 |
| A-5 | Willow Creek near Granum Monthly Mean Flow Adjustments ..... | 31 |
| A-6 | Willow Creek near Nolan Monthly Mean Flow Adjustments ..... | 32 |
| A-7 | Trout Creek near Granum Monthly Mean Flow Adjustments ..... | 33 |
| A-8 | Meadow Creek at Hart's Ranch Monthly Mean Flow Adjustments ..... | 34 |
| A-9 | Meadow Creek near the Mouth Monthly Mean Flow Adjustments ..... | 35 |
| A-10 | Kyiskap Creek near Granum Monthly Mean Flow Adjustments ..... | 36 |
| A-11 | Willow Creek at the Mouth Monthly Mean Flow Adjustments ..... | 37 |
| APPENDIX B | ..... | 38 |
| B-1 | Willow Creek above Chain Lakes Monthly Mean Discharges ..... | 39 |
| B-2 | Willow Creek below Lane Creek Monthly Mean Discharges ..... | 40 |

| Table Number | Item | Page Number |
|---|---|---|
| B-3 | Willow Creek near Claresholm Monthly Mean Discharges ..... | 41 |
| B-4 | Willow Creek near Granum Monthly Mean Discharges ..... | 42 |
| B-5 | Willow Creek near Nolan Monthly Mean Discharges ..... | 43 |
| B-6 | Trout Creek near Granum Monthly Mean Discharges ..... | 44 |
| B-7 | Meadow Creek at Hart's Ranch Monthly Mean Discharges ..... | 45 |
| B-8 | Meadow Creek near the Mouth Monthly Mean Discharges ..... | 46 |
| B-9 | Kyiskap Creek near Granum Monthly Mean Discharges ..... | 47 |
| APPENDIX C ..... | | 48 |
| C-1 | Willow Creek above Chain Lakes Recorded Monthly Flows Adjusted to Natural .. | 49 |
| C-2 | Willow Creek below Lane Creek Recorded Monthly Flows Adjusted to Natural .. | 50 |
| C-3 | Willow Creek near Claresholm Recorded Monthly Flows Adjusted to Natural .. | 51 |
| C-4 | Willow Creek near Granum Recorded Monthly Flows Adjusted to Natural .. | 52 |
| C-5 | Willow Creek near Nolan Recorded Monthly Flows Adjusted to Natural .. | 53 |
| C-6 | Trout Creek near Granum Recorded Monthly Flows Adjusted to Natural .. | 54 |
| C-7 | Meadow Creek at Hart's Ranch Recorded Monthly Flows Adjusted to Natural .. | 55 |
| C-8 | Meadow Creek near the Mouth Recorded Monthly Flows Adjusted to Natural .. | 56 |
| C-9 | Kyiskap Creek near Granum Recorded Monthly Flows Adjusted to Natural .. | 57 |

| Table Number | Item | Page Number |
|---|---|---|
| C-10 | Highwood River near Aldersyde<br>Recorded Monthly Flows Adjusted to Natural .. | 58 |
| C-11 | Stimson Creek near Pekisko<br>Recorded Monthly Flows Adjusted to Natural .. | 59 |
| APPENDIX D | ..... | 60 |
| D-1 | Willow Creek near Nolan<br>Natural Flows Extended ..... | 62 |
| D-2 | Trout Creek near Granum<br>Natural Flows Extended ..... | 64 |
| D-3 | Willow Creek near Claresholm<br>Natural Flows Extended ..... | 66 |
| D-4 | Willow Creek above Chain Lakes<br>Natural Flows Extended ..... | 68 |
| D-5 | Meadow Creek near the Mouth<br>Natural Flows Extended ..... | 70 |
| D-6 | Kyiskap Creek near Granum<br>Natural Flows Extended ..... | 72 |
| D-7 | Willow Creek below Lane Creek<br>Natural Flows Extended ..... | 74 |
| APPENDIX E | ..... | 75 |
| E-1 | Pine Creek at Potential Damsite #1<br>Generated Monthly Flows ..... | 76 |
| E-2 | Willow Creek at Potential Diversion to Site #2<br>Generated Monthly Flows ..... | 77 |
| E-3 | Willow Creek at Potential Damsite #2A<br>Generated Monthly Flows ..... | 78 |
| E-4 | Willow Creek at Potential Damsite #3<br>Generated Monthly Flows ..... | 79 |

## LIST OF FIGURES


| Figure Number | Item | Page Number |
|---|---|---|
| 2.1 | Willow Creek Basin Boundaries and Location of Hydrometric Stations ... | 4 |
| APPENDIX A | ..... | 13 |
| A-1 | Willow Creek above Chain Lakes Upstream licenced Uses ..... | 18 |
| A-2 | Willow Creek below Lane Creek Upstream licenced Uses ..... | 19 |
| A-3 | Willow Creek near Claresholm Upstream licenced Uses ..... | 20 |
| A-4 | Trout Creek near Granum Upstream licenced Uses ..... | 21 |
| A-5 | Meadow Creek at Hart's Ranch Upstream licenced Uses ..... | 22 |
| A-6 | Meadow Creek at the Mouth Upstream licenced Uses ..... | 23 |
| A-7 | Willow Creek near Granum Upstream licenced Uses ..... | 24 |
| A-8 | Kyiskap Creek near Granum Upstream licenced Uses ..... | 25 |
| A-9 | Willow Creek near Nolan Upstream licenced Uses ..... | 26 |
| A-10 | Willow Creek at the Mouth Upstream licenced Uses ..... | 27 |

# WILLOW CREEK NATURAL FLOWS

## 1. INTRODUCTION

Licences for the consumptive use of water, from the Willow Creek basin, were first issued in the late 1800's. These early licences were issued for gravity irrigation projects which apparently were constructed to "prove up" the land and so acquire it under the homestead regulations of that period. Between 1900 and 1963 the demand for water in the basin remained relatively constant. Since 1963, however, there have been numerous projects constructed and as a result the basin demand for water increased seven fold to its present (end of 1984) level of approximately 23,000 acre-feet. While irrigation remains the prime user demands for municipal, industrial, recreational, and environmental uses are becoming increasingly important.

Regional planning studies, conducted in the mid-seventies, recognized that, with the rapid rate of increase in demands, difficulties would be experienced in meeting the agricultural water demands from Willow Creek, towards the mid-eighties. These reports went onto recommend that detailed studies be conducted so as to develop a water resource management strategy for the Willow Creek basin.

Water management concerns for the basin became even more apparent in 1977 and 1984 when significantly below average summer runoff combined with the presently high level of demand to create severe water shortages throughout the lower reaches of the basin. In view of these shortages, Planning Division of Alberta Environment initiated a study, late in 1984, to assess various water management strategies and to develop a water management plan for the Willow Creek basin. The method chosen for assessing the success of selected water management alternatives was to determine the water supply for a historical period and to then test the success of alternatives by superimposing them on the historical period.

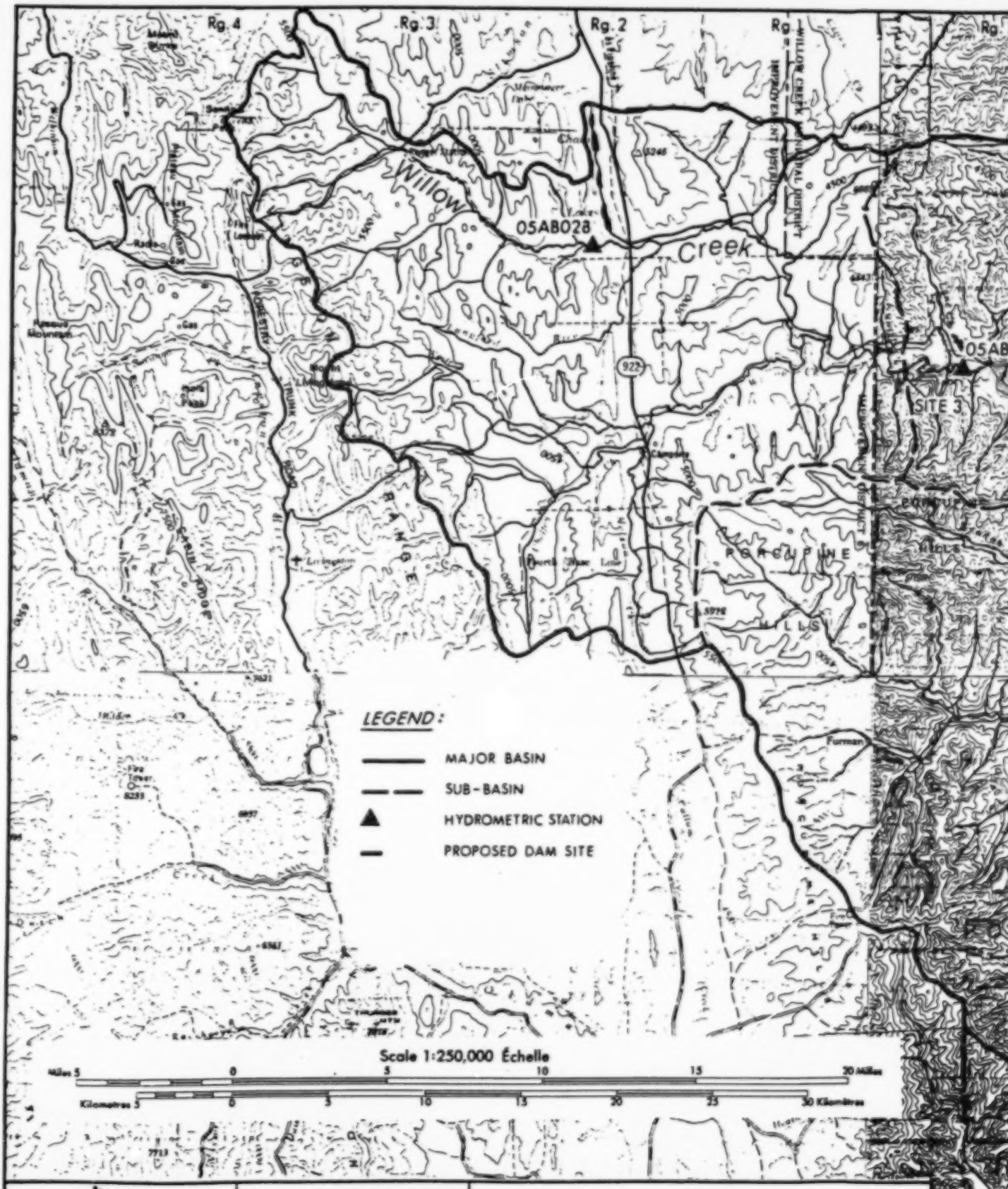
This report presents the method and results of a study to develop monthly mean natural flows, for 1912 to 1983, at seven hydrometric station locations and four points of interest within the Willow Creek basin. As the recorded streamflow data base, for Willow Creek, reflects historical patterns of water use and since the present and future water uses are different than actual historical patterns; an important part of the process was the removal of the effects of historical uses from the data set so as to develop a set of natural streamflows. Also, since the recorded streamflow data base is relatively incomplete; an equally important part of the process was the development of equations which could be used to transfer information from nearby hydrometric stations to stations in the basin and thus extend the recorded period to the study period. Lastly, it was necessary to transfer the extended, naturalized data set from the gauging locations to points of interest with no records.

This report on the natural flow of the Willow Creek basin is composed of sections which describe the basin geography (Section 2), the analytical approach of the study (Section 3), water use within the basin (Section 4), the derivation of historical natural flows at gauging locations (Section 5) and the derivation of historical natural flows at ungauged points of interest - Project Sites (Section 6).

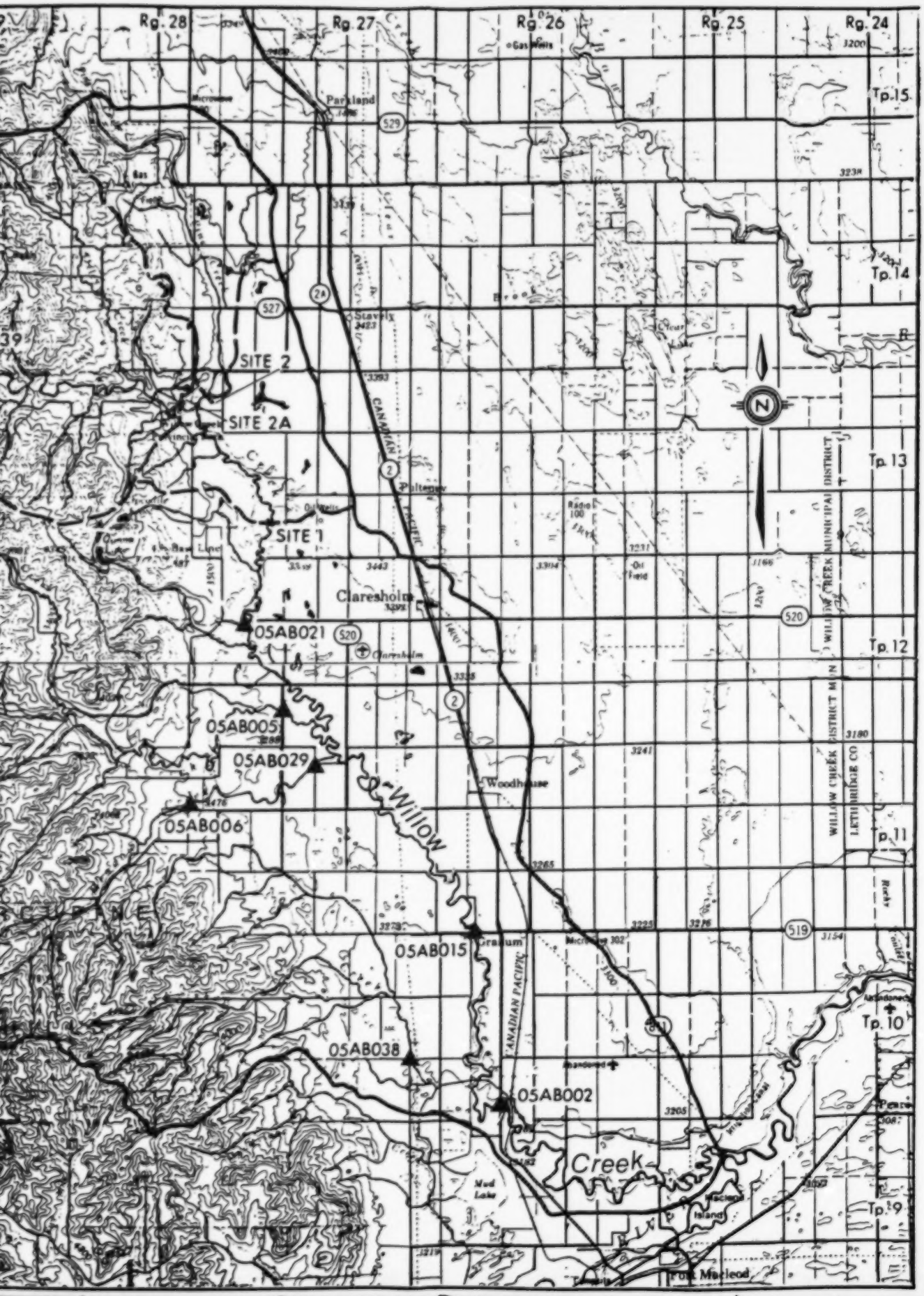
## 2. BASIN GEOGRAPHY

The Willow Creek Basin (Figure 2.1) is situated in south-western Alberta approximately 30 miles north-west of the City of Lethbridge. Originating on the eastern slopes of the Livingstone Range, near Mount Burke, it flows in a south-easterly direction for a distance of approximately 15 miles before draining into the man-made Chain Lakes Reservoir. From the reservoir it continues easterly, then swings into a southerly direction for a distance of four miles where its is joined by South Willow Creek, a tributary which also originates in the Livingstone range. From its confluence with South Willow Creek the stream swings into an easterly direction for a distance of 15 miles. While flowing eastward, Willow Creek is joined by a number of smaller streams, which include Lee Creek, Oxley Creek, and Pine Creek, draining a foothills area to the north. From this point Willow Creek swings into a southerly course through the western plains for a distance of 30 miles and receives waters from Trout Creek, Meadow Creek, and Kyiskap Creek; all streams originating in the Porcupine Hills, before emptying into the Oldman River one mile east of Fort MacLeod.

Mean annual precipitation ranges from a high in excess of 26 inches for the mountain region in the extreme north-western corner of the basin and rapidly decreases to less than 16 inches for the plains region in the eastern reaches of the basin. Conversely, mean annual gross evaporation ranges from a low of approximately 27 inches in the extreme north-western corner of the basin to a high of approximately 30 inches in the south-eastern corner.




| | | |
|---|---|---|
| Alberta ENVIRONMENT | TECHNICAL SERVICES DIVISION **HYDROLOGY BRANCH** | WILLOW CREEK |
| SUBMITTED S. FIGLIUZZI, P. ENG. DATE JUNE, 1985 | DESIGNED G. W. GUENTHER CHECKED | |
| APPROVED M. MUSTAPHA, P. ENG. DATE JUNE, 1985 | DRAWN V. DA SILVA CHECKED G. W. GUENTHER | SCALE 1: 250,000 DATE JUNE, 1985 — FIGURE No. 1 |


Rg. 28
Rg. 27
Rg. 26
Rg. 25
Rg. 24
Tp. 15
Tp. 14
Tp. 13
Tp. 12
Tp. 11
Tp. 10
Tp. 9
SITE 2
SITE 2A
SITE 1
05AB021
05AB005
05AB029
05AB006
05AB015
05AB038
05AB002
Claresholm
Willow
Creek
Parkland
Stavely
Poltergy
Woodhouse
Granum
Fort Macleod
CANADIAN PACIFIC
WILLOW CREEK DISTRICT M.D.
LETHBRIDGE CO
529
527
520
519
2
2A
N

## 3. STUDY APPROACH

The primary objective of the study is the development of a historical (1912-1983) natural streamflow data base which will allow the assessment of water management alternative for the Willow Creek basin. Towards this objective, monthly mean natural flow files will be required for the following seven hydrometric station locations and three project sites:

TABLE 3.1: Locations of Historical Natural Flow Files

A. LOCATION OF HYDROMETRIC STATIONS

| | Station Code | Drainage Area ($km^2$) | Station Name |
|---|---|---|---|
| 1. | C5AB002 | 2290 | Willow Creek near Nolan |
| 2. | C5AB005 | 440 | Trout Creek near Granum |
| 3. | C5AB021 | 1160 | Willow Creek near Claresholm |
| 4. | C5AB028 | 163 | Willow Creek above Chain Lake |
| 5. | C5AB029 | 130 | Meadow Creek near the Mouth |
| 6. | C5AB038 | 191 | Kyiskap Creek near Granum |
| 7. | C5AB039 | 730 | Willow Creek below Lane Creek |

B. LOCATION OF POINTS OF INTEREST

| | Station Code | Drainage Area ($km^2$) | Location | Purpose |
|---|---|---|---|---|
| 1. | GA1 | 1117 | Willow Creek @ 12-13-28-W4 | Inflow to potential reservoir |
| 2. | GA2 | 87.2 | Pine Creek @ 31-13-28-W4 | Inflow to potential reservoir |
| 3. | GA2A | 950 | Willow Creek @ 31-13-28-W4 | Potential point of diversion |
| 4. | GA3 | 682 | Willow Creek @ 2-14-30-W4 | Inflow to potential reservoir |

Since the monthly streamflow records for the hydrometric station locations reflect human activity in the basin and relatively incomplete, the monthly mean natural flows at these sites had to be reconstructed before they could be utilized in the assessment of water management alternatives. Also, since there are no streamflow records at

the points of interest it was necessary to transfer streamflow information from the hydrometric station locations to these sites in order to develop the required data base.

The naturalization of recorded flows at the hydrometric station locations was carried out using the project depletion method. The procedure starts with the monthly recorded streamflows (the A Files) and adjusts the recorded streamflows by adding or subtracting the monthly consumptive uses (the J Files) due to man-made projects. The result is a set of monthly natural streamflows (the B Files). Since the naturalized record may not encompass the entire study period of 1912 to 1983, the next step was to extend the recorded period to the study period. This was done by correlating the B Files for each hydrometric station location with B Files and/or non-regulated streamflow records of other nearby hydrometric stations having a more complete data base. Equations resulting from the correlation were subsequently used to fill in the missing data for hydrometric station locations in the Willow Creek basin. The complete study period natural flows at hydrometric station locations are termed the C Files. For the four points of interest where no streamflow data exists, the natural flows were derived by calculations based on the C-Files. The natural streamflow data for the points of interest are contained in the G-File.

## 4. BASIN WATER USE

Historical basin water use (the J-File) is defined as the monthly flow adjustment which must be added to the recorded flows at a gauging station in order to reconstruct the natural monthly flows at that site. Since the monthly flow adjustment for a site represents the integrated effect of all upstream water use projects, the first step in the analysis is the identification of all upstream water use projects and their period of operation. For the purpose of this study, a water use project has been defined as consisting solely of licenced and/or authorized projects which are located within the effective drainage area of the basin, and which consume or modify the flow which would have been experienced in Willow Creek. While it is realized that this definition neglects the effects of drainage projects, land use changes, unlicenced withdrawals, and withdrawals from non-effective areas; it was felt that the modifying effects of these projects would be negligible or non-quantifiable and therefore could be omitted from the analysis. Based on this definition, water use projects within the Willow Creek basin were identified from Alberta Environment's computer files of water rights projects. The projects were subsequently assembled according to their location relative to hydrometric gauging sites and are presented in Appendix A, Table A-1. Table A-1 also provides a listing of the year the project was authorized, the purpose, the area being irrigated (where applicable), the quantity of water allocated, reservoir specifications (where applicable), and upstream drainage areas.

Having identified the water use projects in the basin, it was necessary to determine the quantity and time distribution of consumptive uses. The method initially proposed for this aspect of the study was to assume that all licenced projects come into effect one year after the date of authorization, and received their full allocation every year. However, after reviewing Table A-1 and Water Rights files, it becomes apparent that the drainage area upstream of many of the licences was inadequate in terms of supplying the allocated quantity during years of below average runoff and that the use of the above noted procedure would result in an over-estimation of the adjustments required to naturalize

monthly flows. In this regard, the procedure for the derivation of historical water uses was modified such that, with the exception of domestic licences, only consumptive uses which could be reliably quantified, from water use reports and/or correspondence in Water Rights files, were incorporated in the analysis. Domestic licences account for less than 1% of all licences, are generally located near local springs and were therefore assumed to receive their full allocation every year. Monthly consumptive uses, for upstream of each of the gauging locations, computed by this procedure are summarized in Appendix A, tables A-2 to A-10. Figures A-1 to A-10, Appendix A provide a visual summary as to the total licenced volume for upstream of each of the gauging locations as well as the volume allocated to licences which did not report the quantity consumed in a given year. Figure A-10 reads that in 1983 the total licenced allocation was approximately 17,500 acre feet and the total allocation to licences which did not report their actual consumption for the year was approximately 2,800 acre-feet.

## 5. NATURAL FLOWS FOR HYDROMETRIC SITES

Natural flow is the flow of water which would occur at a particular site if there was no upstream human interference. Natural flows for the nine Water Survey of Canada (WSC) hydrometric stations in the Willow Creek basin were computed by adding the historical water uses by projects upstream of each recording station (J-Files in Appendix A, Tables A-2 to A-10) to the recorded flows (A-Files in Appendix B, Tables B-1 to B-9) at the corresponding station. The resulting arrays of monthly natural flows for each recording site (the B-Files) are presented in Appendix C, Tables C-1 to C-9.

The streamflows (B-files) created by the above procedure represent the calculated natural flows for the period of record at the hydrometric stations. Since the period of record at the hydrometric stations does not encompass the entire study period of 1912 to 1983, the next step was to extend the recorded period to the study period. Extension of the recorded period to the study period was carried out by correlation analyses. In the correlation analysis, the B-File for each station identified in Section 3 was correlated to the B-Files of all combinations of the other hydrometric stations in the Willow Creek basin* using a stepwise logarithmetic linear regression so as to develop regression equations which could be used to estimate missing hydrometric records. The resulting regression equations were then ranked in terms of priorities with the highest priority being assigned to the equation which, based on the adjusted (to account for the degrees of freedom) standard error of estimate and the adjusted coefficient of correlation, gave the best estimate for missing hydrometric records. The regression equation which gave the best estimate of monthly streamflow and which was assigned priority No. 1 was then used to estimate as many values as possible for a particular station. The regression equation assigned

* Included in the correlation analysis are B-File data for station 05BL009 (Highwood River near Aldersyde) and 05BL007 (Stimson Creek near Pekisko) which were generated for the 'South Saskatchewan River Basin Historical Natural Flows' study of 1982 and which are duplicated in Appendix B, Tables B-10 and B-11.

priority No. 2 was then used to estimate values not filled in by the first priority and so on. In all cases the resulting values were visually inspected to ensure that they were physically reasonable. The resulting extended (1912 to 1983) natural flow arrays (C-Files) for hydrometric stations in the Willow Creek basin are presented in Appendix D, Tables D-1 to D-7. The regression results are presented in Appendix D in a supplementary table opposite the corresponding natural flow array.

## 6. NATURAL FLOWS AT PROJECT SITES

The Willow Creek basin planning study required that estimates of monthly natural flows be developed at four locations which are not hydrometric stations. These locations have been termed as 'project sites' and are listed in Table 3.1 of Section 3.

Arrays of monthly natural flows for the project sites (G-Files) were derived from data in the C-Files and were based upon drainage area ratios between the project site and appropriate C-Files. Where C-File data were available for points both upstream and downstream of a project site, the G-File data was derived using the following area relation:

$$Q_{ps} = Q_u + [Q_d - Q_u] \times [\frac{A_{ps} - A_u}{A_d - A_{ps}}] \qquad ...(1)$$

where, Q is the monthly natural flow
A is the gross drainage area while the subscripts ps, u, and d represent the project site and upstream and downstream C-file data sites respectively.

Where C-File data was available for a single point, either upstream or downstream of project site or on a nearby representative stream, the G-File data was derived using the following area relation:

$$A_{ps} = Q_c \times A_{ps}/A_c \qquad ...(2)$$

where, the subscript 'c' represents the C-File data site.

The resulting natural flow arrays for each of the four project sites are presented in Appendix E, Tables E-1 to E-4.

## 7. DISCUSSION OF RESULTS

This study has produced a set of monthly natural flows at seven hydrometric station locations and four project sites in the Willow Creek basin. The natural flows for the hydrometric station locations were derived from streamflow records, reservoir data, recorded project water use information and climate data. In the naturalization of flows, all licenced man-made projects with sufficient data to quantify the quantity of water consumed have been accounted for in years when their consumption could be quantified. Licenced projects having no information on which to quantify their water use were not included in the naturalization of flows. The total licenced quantity for projects having no water use information is in the order of 3500 acre-feet or approximately 1% of the flow in the basin. The actual water use by these licences is believed to be substantially lower. This is especially true in years of low flow when there is insufficient water to meet their demands. In this regard, it is felt that the omission of these water uses has not affected the general high level of quality of the derived data.

# APPENDIX

NOT

FILMED